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(54) **ANTI-ICING SYSTEM**
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## Description

The present invention relates to an anti-icing system in a gas turbine powerplant and, more particularly, to exhaust means for anti-ice fluid flowing through a nacelle cavity.

A typical aircraft powerplant, such as an axial flow gas turbine engine, includes a nacelle which extends about the engine. The nacelle is the radially outermost structure of the powerplant. The nacelle extends forward of the gas turbine engine to define an inlet for working fluid to enter the gas turbine engine. The gas turbine engine includes a flowpath in communication with the fluid inlet of the nacelle. The flowpath extends sequentially through a compressor section, a combustion section and a turbine section. The compression section and turbine section include many components susceptible to impact damage, such as rotating blades which extend across the flowpath and interact with the working fluid.

Safety is a primary concern in the design of powerplants to be used in aircraft applications. One hazard to be avoided is the build-up of ice on the engine and the structure surrounding the engine. The build-up of ice presents many problems. First, ice may add considerable weight to the engine and to the aircraft. Second, the build-up of ice near the inlet of the nacelle may adversely affect the flow of working fluid into and through the engine.

Another concern with powerplants is the useful life of the powerplant and components. The build-up of ice near the inlet of the engine may lead to large pieces of ice breaking loose from the inlet and flowing into the gas turbine engine. Ice flowing into and through the engine may damage components within the engine such as the blades and components attached to the nacelle, such as inlet acoustic panels. The damaged components may then require replacement.

Not surprisingly anti-ice systems for the inlet area of nacelles have been the focus of a significant amount of research and development within the aircraft industry. An example of this is U.S. Patent No. 4,688,745 entitled "Swirl Anti-Ice system" and issued to Rosenthal. This patent discloses a system for injecting hot gases into an annular cavity located on the leading edge of the nacelle. The cavity extends circumferentially about the inlet. The hot gases are injected into the cavity in a direction tangential to the circumferential direction. The tangential injection produces a circumferentially flowing body of hot gases within the cavity. Exhaust vents or holes located in a bulkhead of the nacelle allow gases within the cavity to escape into the external medium flowing around the powerplant. The venting of the anti-ice fluid prevents over-pressurization of the cavity in the event of an anti-ice fluid flow regulator failure. The exhaust holes lie in a plane parallel to the direction of flow to avoid direct impingement of the body of fluid on the exhaust holes.

The anti-ice system disclosed in U.S. Patent No. 4,688,745 is effective at reducing the build-up of ice on the inlet of the nacelle. There are, however, drawbacks to the use of this anti-ice system. The exhaust fluid removed through the exhaust holes is typically flowed into a chamber within the nacelle. The exhaust fluid exits the nacelle through a vent and flows into the external medium flowing about the nacelle. Flowing the exhaust gases through the nacelle structure may lead to overheating of the nacelle in the vicinity of the chamber.

Further, the fluid exiting the vent tends to be held against the outer barrel skin by the external medium flowing past the outer skin (the free stream). This may lead to overheating of the nacelle surface downstream of the vent. Overheating of the nacelle is especially significant if the nacelle is made from lightweight composite materials. These composite materials are typically bonded together with an adhesive having a lower melting temperature than traditional metallic materials. The rate of temperature decay downstream of the vent is dependent upon the size of the vent and a blowing parameter. Large values for the area of the vent result in a low rate of decay of temperature downstream of the vent. Small values of the blowing parameter, defined as the ratio of exhaust exit velocity to free stream velocity, also result in a low rate of decay of temperature downstream of the vent. The effects of vent size and blowing parameter on the rate of decay of temperature are cumulative.

The vent also introduces aerodynamic penalties in the form of increased drag of the nacelle when the anti-ice system is shut off. The drag caused by the vent is dependent upon the size of the vent and the axial location of the vent. The larger the exit area of the vent or the closer the vent is to the leading edge of the nacelle, the greater the drag attributable to the vent.

A solution to the overheating of the nacelle caused by the exhaust flow through the nacelle is to duct the exhaust flow from the cavity to the vent Ducting the exhaust fluid through the nacelle structure reduces the likelihood of overheating of the nacelle in the vicinity of the chamber, but also increases the size and weight of the nacelle structure. Attempts to decrease the bulk of the ducts by moving the exhaust vent forward, and thereby shortening the length of the duct, increase the aerodynamic drag of the vent. In addition, the duct does not prevent overheating of the nacelle surface downstream of the vent.

EP-A-0205283 discloses an anti-ice system which channels spent hot air from within the nacelle through an exhaust duct to an exhaust aperture in the surface of the nacelle, and further provides a heat shield in the skin downstream of the exhaust aperture.

FR-59222 also discloses ejecting spent hot air from within the nacelle.

The above art notwithstanding, there is still a need to develop efficient anti-icing systems for the nacelle of a gas turbine powerplant.

The invention is predicated in part upon recognition by the Applicants of the availability within the cavity of a dynamic pressure head to increase the velocity of the exhaust fluid exiting the cavity. Prior art exhaust means rely upon the static pressure differential between the cavity and the environment external to the cavity to produce the exhaust flow. This resulted in low exit velocities for the exhaust fluid and, consequently, large exhaust vents to provide an adequate, volumetric flow rate of exhaust fluid out of the cavity. The combination of small blowing parameter and large vent size resulted in overheating of the nacelle external surface. Using the dynamic pressure head available from the circumferentially flowing body of fluid increases the exit velocity and decreases the size of the exhaust vent required.

According to the present invention, there is provided an anti-icing system in a powerplant having a longitudinal axis, a source of heating fluid, and a nacelle defining a fluid inlet and a radially outer boundary for the powerplant, the nacelle having an annular cavity disposed about the inlet, the anti-icing system including means to flow heating fluid from the source to the cavity; means to inject heating fluid into the cavity, the injection means being adapted to generate a body of fluid flowing within the cavity with a circumferentially directed component of velocity; and means to exhaust fluid from the cavity into a medium external of the nacelle, characterised in that:

the exhaust means comprises vanes within the cavity which are adapted to turn a portion of the fluid flowing within the cavity to a direction substantially normal to the direction of flow of the medium external of the nacelle and to eject the fluid from the cavity into the external medium at a flow velocity sufficient to penetrate the external medium.

According to a specific embodiment of the present invention, the exhaust means includes a plurality of aerodynamic vanes disposed within the cavity and on the radially outer portion of the nacelle, a plurality of vent slots disposed between adjacent vanes, an upstream fairing, and a downstream fairing, wherein the plurality of vanes are adapted to turn a portion of the circumferentially flowing body of fluid such that the turned portion of the fluid passes through the slots and out of the cavity. Each of the vanes extend in a direction normal to the principal direction of flow within the cavity. Each of the slots is disposed adjacent to, parallel with, and upstream of relative to the principal direction of flow within the cavity, one of the vanes.

A principal feature of the present invention is the plurality of aerodynamically, bluntly shaped vanes disposed within the cavity. Another feature is the plurality of exhaust slots. A further feature is the fairings located upstream and downstream of the vanes and slots.

A primary advantage of the present invention is the rate of decay of temperature downstream of the exhaust vent as a result of the exhaust fluid ejection angle, the blowing parameter of the exhaust means, and the size of the exhaust slots. The exhaust fluid is ejected through the plurality of small exhaust slots at an ejection angle substantially normal to the free stream flow direction and with sufficient velocity to penetrate the external medium flowing over the exhaust means. The penetration of the free stream creates a separation between the hot exhaust fluid and the nacelle and prevents reattachment of the exhaust fluid to the surface of the nacelle. Another advantage is the level of efficiency of the exhaust means as a result of the utilization of the dynamic pressure head within the cavity to produce the exhaust flow. The aerodynamic vanes interact with the fluid in the cavity to redirect a portion of it through the slots, rather than relying upon static pressure only to urge the fluid out of the cavity. A further advantage is the reduced aerodynamic drag of the vent, relative to prior art vents, as a result of the reduced size of the vent. The reduced vent size is a result of the increased velocity of the exhaust fluid ejected from the cavity. Another advantage is the tolerance of the exhaust means for non-circumferential flows within the cavity, such as helical flows, as a result of the bluntly shaped vanes. A further advantage is the minimal flow losses within the cavity as a result of the fairings which provide smooth changes in flow area and prevent flow separation from occurring. Minimizing flow losses within the cavity maximizes the pressure differential available to eject the exhaust fluid from the cavity.

Although the invention is shown and described as means to exhaust fluid from a cavity having a circumferentially flowing body of fluid, the invention is equally applicable for cavities having other types of flow, such as a spiraling or helical flow about a circumferential axis through the annular cavity.

The foregoing and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of the exemplary embodiments thereof, as illustrated in the accompanying drawings.

Brief Description Of The Drawings

FIG. 1 is a cross-sectional view of a gas turbine engine and a nacelle in accordance with the present invention.

FIG. 2 is a cross-sectional view taken along line 2-2 of FIG. 1 to show a cross-sectional view of a plurality of exhaust vanes.

FIG. 2 is a perspective view, partially cut away, of the exhaust means.

FIG. 4 is a view taken along line 4-4 of FIG. 1, and shows the plurality of exhaust slots.

FIG. 5 is a cross-sectional view of an exhaust vane.

FIG. 6 is a plot of temperature decay as a function of a non-dimensionalized distance downstream of a vent.

A gas turbine powerplant 12 is illustrated in FIG. 1. The powerplant 12 is disposed about a longitudinal axis 14 and includes an axial flow gas turbine engine 16 and a nacelle 18. The gas turbine engine 16 includes an axially extending flowpath 22, a compression section 24, a diffuser case 25, a combustion section 26, and a turbine section 28. Incoming fluid passes through the nacelle 18 and into the compression section 24 of the gas turbine engine 16. Working fluid is compressed within the compression section 24 which results in an increase in momentum of the working fluid and an increase in temperature of the working fluid. From the compression section 24 the working fluid flows through the diffuser case 25 and into the combustion section 26 where fuel is mixed with the working fluid and the mixture is combusted. The products of combustion are then expanded through the turbine section 28 and then flowed out of the gas turbine engine 16.

The nacelle 18 extends forward of the gas turbine engine 16 and defines an inlet 32 for incoming fluid. The nacelle 18 includes an inner barrel 34, an outer barrel 36, a bulkhead 38, and an inlet shell 42. The inner barrel 34 defines a radially outer flow surface 44 for a portion of the flowpath of the gas turbine engine 16. The outer barrel 36 defines an outer flow surface 46 for the external medium flowing about the gas turbine engine 16. A radial separation between the inner barrel 34 and the outer barrel 36 defines an annular chamber 48 therebetween. The inlet shell 42 is the leading edge for the nacelle. The inlet shell 42 and the bulkhead 38 bound an annular shell cavity 52.

The powerplant 12 includes an anti-ice system 54. The anti-ice system 54 includes a conduit 56, a nozzle 58, and exhaust means 62. The conduit 56 extends between the diffuser case 25 of the gas turbine engine 16 and the shell cavity 52. Although not shown in FIG. 1, the conduit 56 may include a variety of valves and flow regulators to control the flow of fluid through the conduit. The diffuser case 25 is a source of high temperature, high pressure fluid. The nozzle 58 is attached to an outlet end 64 of the conduit 56 and extends within the shell cavity 52. The exhaust means 62 provides fluid communication between the shell cavity 52 and the external medium flowing about the powerplant 12. The exhaust means 62 is disposed on the radially outer portion and axially downstream end of the inlet shell 42. Although the exhaust means 62 may be located at various circumferential positions around the inlet 32, stability of the pressure field of the medium external to the exhaust means 62 may require consideration. As is well known, in aircraft applications a position 180° from top dead center is a region of stable pressure. Therefore, for aircraft applications it is suggested that the circumferential location of the exhaust means 62 be 180° from top dead center.

Referring now to FIGs. 2-4, the exhaust means 62 is located circumferentially adjacent to and upstream of relative to the flow within the shell cavity 52, the nozzle 58. This location removes fluid which has transferred heat as it travelled around the circumference of the shell cavity 52. In effect, the exhaust means 62 removes relatively cool exhaust fluid from the shell cavity 52.

The exhaust means 62 includes a plurality of vanes 66, a plurality of exhaust slots 68, an upstream fairing, 69, a downstream fairing 70, and an axially adjacent wall 72. The plurality of exhaust vanes 66 extend radially inward from the inlet shell 42 and into the shell cavity 52. The plurality of vanes 66 also extend axially. Each vane 66 is aerodynamically shaped to engage the body of fluid flowing circumferentially within the shell cavity. As shown in FIG. 5, the vanes have a rounded leading edge 74 which adapts the vanes to engage with fluid flowing at off angles relative to the circumferential direction. The roundness of the vane leading edge 74 is defined by the ratio of leading edge 74 diameter d, measured as shown in FIG. 5, to maximum thickness t, measured in the circumferential direction. To accommodate off angle flow within the shell cavity 52, it is suggested that the ratio d/t be between 0.4 and 0.6. The shape of the vanes 66 is also dependent upon the ratio of maximum thickness t to vane length l. It is suggested that the ratio t/l be between 0.3 and 0.5. While the vanes 66 have been described with respect to various ratios of length l, thickness t, and leading edge diameter d, it will be appreciated by those skilled in the art that the values of these ratios vary with application and the suggested ranges of values may be transgressed without departing from the scope of the invention.

Each of the exhaust vanes 66 is circumferentially adjacent to and downstream of, relative to the direction of flow of the body of fluid within the shell cavity 52, one of the plurality of exhaust slots 68. The plurality of exhaust slots 68 extend radially through the inlet shell 42 and provide means of communication between the shell cavity 52 and the external medium. The exhaust slots 68 are circumferentially adjacent each other and extend in an axial direction as shown in FIG. 4.

The upstream fairing 69 provides a smooth transition from the flow surface of the inlet shell 42 to the vanes 66. The downstream fairing 70 provides a smooth transition from the vanes 66 back to the flow surface of the inlet shell 42. The fairings 69, 70 eliminate abrupt changes in cross-sectional area within the shell cavity 52. In accordance with conventional fluid mechanics, the fairings 69, 70 produce smooth flow lines over the exhaust means 62 and uniformly distribute the exhaust flow through the exhaust slots 68. Without the fairings 69, 70, an unequal distribution of the flow through the slots would occur. Unequal distribution implies a flow separation, with corresponding flow losses and inefficiencies, within the shell cavity 52.

FIGs. 1-4 show exhaust means having five (5) vanes and six (6) slots. The quantity and size of the vanes and slots is dependent upon the flow characteristics of the shell cavity and the flow rate of the source of high temperature, high pressure fluid. The quantity and size of the vanes and slots must be sufficient to prevent over-pressurization of the shell cavity when subjected to the maximum output of the source of hot fluid. In addition, the quantity and size of the vanes and slots must permit sufficient pressurization of the shell cavity to produce adequate flow velocity through the slots and penetration of the external flow. Temperature considerations dictate having multiple small slots to increase the rate of temperature decay of the fluid exiting each slot. A plurality of small slots produce a higher rate of temperature decay than a single large opening.

During operation of the gas turbine engine 16, compressor discharge fluid is removed from the diffuser case 25. The combustion section 26 is a source of high pressure, high temperature fluid (relative to the external medium) which may be used as heating fluid in the anti-ice system. The fluid is then flowed through the conduit 56, is ejected through the nozzle 58 and into the shell cavity 52. The conduit 56 provides means to flow the high temperature, high pressure fluid into the shell cavity 52. As shown in Figs. 1 and 2, the fluid is ejected from the nozzle 58 in a direction tangential to the circumferential direction. The nozzle 58 provides means to inject fluid into the shell cavity 52 to generate a flowing body of fluid. The high pressure fluid exits the nozzle 58 with sufficient velocity to entrain the body of fluid within the shell cavity 52 and produce a body of fluid having a principal component of velocity directed in the circumferential direction.

Exhaust means 62 is necessary to prevent overpressurization of the shell cavity 52. The exhaust means 62 removes fluid from the radially outermost and axially downstream section of the shell cavity 52. The exhaust vanes 66 turn a portion of the flow such that the exhaust fluid is ejected from the cavity with an ejection angle $\alpha$ defined by the angle formed by the direction of the exhaust flow and the external surface of the nacelle, equal to 90°. Redirecting the flow to a direction substantially normal to the direction of flow of the external medium maximizes the rate of decay of temperature downstream of the exhaust slots 68.

The exhaust vanes 66 utilize the dynamic pressure head within the shell cavity in addition to the static pressure head to urge the fluid through the exhaust slots 68. The combination of dynamic and static pressure heads produces an exhaust flow velocity sufficient to permit the exhaust flow to penetrate the external medium flowing by the exhaust slots 68. By penetrating the external medium a separation is created between the hot exhaust fluid and the nacelle 18. The separation region is a low pressure region which pulls in low temperature external medium. As a result, the exhaust fluid mixes with external medium rather than reattaching to the surface of the nacelle 18. In addition, the high velocity of the exhaust flow permits the total area of the exhaust slots 68 to be reduced relative to prior art exhaust vents.

FIG. 6 is an illustration of test results of measured temperature decay as a function of distance downstream. Temperature decay is the ratio of the difference between surface temperature T and free stream temperature $T_\infty$ to the difference between vent exit temperature $T_0$ and free stream temperature $T_\infty$. Distance downstream is shown as a ratio of x/D, where x is the actual distance and D is the effective diameter of the vent. Effective diameter D is the diameter of a circle equal in area to the vent. In this way the downstream distance is non-dimensional and the size of the vent is parametrically accounted for. The vanes provide means to turn a portion of the fluid flowing within the shell cavity to a direction substantially normal to the flow direction of the external medium flowing over the surface of the inlet shell in the vicinity of the exhaust means. Turning the exhaust flow normal to the free stream direction increases the rate of decay of temperature along the surface downstream of the exhaust means, as shown in FIG. 6. Curve "A" represents a circular vent with an ejection angle $\alpha_A$=35° and a blowing parameter $\beta_A$=0.4. The results used in curve "A" are for comparison purposes and are taken from "Film cooling with injection through Holes: Adiabatic Wall Temperatures Downstream of a circular Hole", ASME Paper No. 68-GT-19, authored by Goldstein, Eckert and Ramsey. Curve "B" represents test results for a circular vent with an ejection angle $\alpha_B$=90° and a blowing parameter $\beta_B$=0.4. Curve "C" represents test results for a slotted vent with an ejection angle $\alpha_C$=90° and a blowing parameter $\beta_C$=0.4. Although turning the exhaust flow from a substantially tangential direction ($\alpha_A$=35°) to a direction normal to the free stream ($\alpha_B$=$\alpha_C$=90°) increases the rate of temperature decay dramatically, improvement in rate of temperature decay may also be produced by ejection angles as low as $\alpha$=60°.

The vanes also provide means to use the dynamic pressure head within the body of fluid flowing in the shell cavity. Using the dynamic pressure head in addition to the static pressure head increases the exit velocity through the exhaust means and decreases the size of the vent required relative to prior art exhaust vents. Higher exit velocity produces a higher blowing parameter $\beta$. Increasing the blowing parameter $\beta$ increases the rate of temperature decay, as shown in FIG. 6. Curves "D" and "E" represent the results for circular and slotted vents, respectively, having a blowing parameter $\beta_D$=$\beta_E$=0.7. Curve "F" represents the results for a circular vent having a blowing parameter $\beta_F$=1.2.

Smaller vent size D results in a larger value for x/D at a given distance X downstream of the exhaust means. Therefore, smaller vents produce increased rates of temperature decay for a given ejection angle $\alpha$ and blowing parameter $\beta$. The size of the vents or slots may be reduced by increasing the exit velocity, and thereby reducing the size of a slot needed to produce a required volumetric flow rate, and by increasing the number of slots, and thereby reducing the size of each slot.

It should be noted that the vanes 66 and slots 68 are shown in FIGs. 1-4 as extending in a direction normal to the circumferential direction, i.e. they extend axially. The vanes 66 are oriented in this direction to maximize the efficiency of the interaction between the body of fluid flowing within the shell cavity 52 and the exhaust means 62. The principal component of velocity for the body of fluid is directed in the circumferential direction. During operation, however, differing thermal boundary layers may build up around the internal flow surfaces of the shell cavity 52 and may result in the body of fluid within the cavity 52 having a non-circumferential component of velocity. The blunt shape of the vanes 66 adapt the exhaust means 62 to accommodate noncircumferential flow and to urge this type of flow into the exhaust means 62. In some situations, it may be desirable to angle the nozzle 58, or a plurality of nozzles 58, to induce a spiralling or helical flow within the shell cavity 52. For such other flow conditions the vanes 66 and slots 68 may be canted relative to the longitudinal axis 14. Canting the vanes 66 may provide more efficient engagement of the exhaust means 62 with the noncircumferential flow within the shell cavity 52. For typical vanes, efficient engagement anticipates vanes extending in a direction substantially normal to the principal direction of the flow the vanes are engaged with.

It should also be noted that, although the diffuser case 25 was described as the source of high temperature, high pressure fluid, other sections of the powerplant 12 may function as a source of high temperature, high pressure fluid. For instance, the compression section 24 may be used. Additionally, the exhaust means 62, though shown and described as ejecting fluid radially outboard of the nacelle, may be disposed to eject fluid radially inward such that the exhausted fluid is recycled into the gas turbine engine 16.

Although the invention has been shown and described with respect to exemplary embodiments thereof, it should be understood by those skilled in the art that various changes, omissions, and additions may be made thereto, without departing from the scope of the invention which is defined by the claims.

## Claims

**1.** An anti-icing system (54) in a powerplant (12) having a longitudinal axis (14), a source (25) of heating fluid, and a nacelle (18) defining a fluid inlet (32) and a radially outer boundary (44) for the powerplant, the nacelle having an annular cavity (52) disposed about the inlet, the anti-icing system including means (56) to flow heating fluid from the source to the cavity; means (58) to inject heating fluid into the cavity, the injection means being adapted to generate a body of fluid flowing within the cavity with a circumferentially directed component of velocity; and means (62) to exhaust fluid from the cavity into a medium external of the nacelle, characterised in that:

the exhaust means comprises vanes (66) within the cavity which are adapted to turn a portion of the fluid flowing within the cavity to a direction substantially normal to the direction of flow of the medium external of the nacelle and to eject the fluid from the cavity into the external medium at a flow velocity sufficient to penetrate the external medium.

**2.** The anti-icing system according to Claim 1, wherein the cavity is defined by an inlet shell (42), and wherein the exhaust means includes an exhaust slot (68) disposed on the radially outer portion of the inlet shell and an aerodynamically shaped exhaust vane (66), the exhaust vane being disposed on the inlet shell, extending radially into the cavity, and being adjacent to and extending parallel to the exhaust slot, the exhaust vane being adapted to engage the body of fluid flowing within the cavity and to urge a portion of the fluid through the exhaust slot.

**3.** The anti-icing system according to Claim 2, further comprising a fairing (69) disposed upstream, relative to the direction of flow of the body of fluid within the cavity, of the exhaust vane and adapted to prevent flow separation from occurring.

**4.** The anti-icing system according to Claim 2 or 3, further comprising a fairing (70), disposed downstream relative to the direction of flow of the body of fluid within the cavity, of the exhaust vane and adapted to prevent flow separation from occurring.

**5.** The anti-icing system according to Claim 2, 3 or 4 wherein the exhaust vane has a maximum thickness t, measured in the circumferential direction, and a rounded leading edge having a leading edge diameter d, and wherein the ratio d/t is between 0.4 and 0.6.

**6.** The anti-icing system according to any of claims 2 to 5, wherein the exhaust vane has a maximum thickness t, measured in the circumferential direction, and a length l, measured in the radial direction, and wherein the ratio t/l is between 0.3 and 0.5.

**7.** The anti-icing system according to any of Claims 2 to 6, wherein the exhaust vane and exhaust slot extend in a direction normal to the direction of flow of the body of fluid within the cavity.

**8.** The anti-icing system according to any of Claims 2 to 7, wherein the exhaust vane and exhaust slot are adapted to eject the fluid in a radially outward direction.

**9.** The anti-icing system according to any preceding claim wherein the exhaust means turns the portion of the fluid such that the fluid is ejected from the cavity in a direction forming an angle $\alpha$ with the surface of the nacelle, the angle $\alpha$ being greater than or equal to 60°.

**10.** The anti-icing system according to any preceding claim wherein the fluid being ejected has a blowing parameter β, defined as the ratio of the magnitude of velocity of the ejected fluid to the magnitude of velocity of the external medium flowing over the nacelle, and wherein the blowing parameter β is greater than or equal to 0.4.

**11.** A method of preventing ice build-up on a nacelle (18) of an aircraft powerplant (12), the powerplant including a source (25) of heating fluid and an anti-icing system (54), the anti-icing system including means (56) to flow heating fluid from the source to a cavity (52) in the nacelle, means (58) to inject heating fluid into the cavity, and means (62) to exhaust fluid from the cavity, the method including the steps of flowing heating fluid from the source to the cavity; injecting heating fluid into the cavity such that the body of fluid within the cavity has a circumferentially directed component of velocity, and ejecting fluid from the cavity into a medium external to the nacelle, the fluid being ejected with a flow velocity sufficient to penetrate the external medium, characterised in that:

the step of ejecting fluid includes turning a portion of the fluid within the cavity to a direction substantially normal to the direction of flow of the external medium by means of an aerodynamic exhaust vane (66) and an exhaust slot (68), the exhaust vane being adapted to engage the body of fluid within the cavity to turn a portion of the fluid and urge the portion of the fluid through the exhaust slot.

**12.** The method according to Claim 11, wherein the step of ejecting fluid includes ejecting the fluid from the cavity in a direction forming an angle α with the surface of the nacelle, the angle α being greater than or equal to 60°.

**13.** The method according to Claim 11 or 12 wherein the step of ejecting fluid includes ejecting the fluid with a blowing parameter β greater than 0.4, the blowing parameter β being defined as the ratio of the magnitude of velocity of the ejected fluid to the magnitude of velocity of the external medium flowing over the nacelle.

## Patentansprüche

**1.** Anti-Vereisungssystem (54) bei einer Kraftmaschine (12) mit einer Längsachse (14), einer Quelle (25) für Heizfluid und einer Gondel (18), die einen Fluideinlaß (32) und eine radial äußere Begrenzung (44) für die Kraftmaschine definiert, wobei die Gondel einen ringförmigen Hohlraum (52) aufweist, der um den Einlaß angeordnet ist, wobei das Anti-Vereisungssystem eine Einrichtung (56) zum Strömenlassen von Heizfluid von der Quelle zu dem Hohlraum, eine Einrichtung (58) zum Einströmenlassen von Heizfluid in den Hohlraum, wobei die Einströmeinrichtung einen Fluidkörper erzeugen kann, der in dem Hohlraum mit einer umfangsmäßig gerichteten Geschwindigkeitskomponente strömt, und eine Einrichtung aufweist zum Ausströmenlassen von Fluid aus dem Hohlraum in ein Medium außerhalb der Gondel,

**dadurch gekennzeichnet**,

daß die Ausströmeinrichtung Leitschaufeln (66) in dem Hohlraum aufweist, die einen Teil des in dem Hohlraum strömenden Fluids in eine Richtung im wesentlichen rechtwinklig zur Strömungsrichtung des Außenmediums der Gondel drehen kann und das Fluid von dem Hohlraum in das Außenmedium mit einer Strömungsgeschwindigkeit abgeben kann, die zum Eindringen in das Außenmedium ausreichend ist.

**2.** Anti-Vereisungssystem nach Anspruch 1, bei dem der Hohlraum durch eine Einlaßverkleidung (42) definiert ist und bei dem die Ausströmeinrichtung einen Ausströmschlitz (68), der an dem radial äußeren Bereich der Einlaßverkleidung angeordnet ist, und eine aerodynamisch geformte Ausström-Leitschaufel (66) aufweist, die an der Einlaßverkleidung angeordnet ist, radial in den Hohlraum ragt und dem Ausströmschlitz benachbart und zu diesem parallel verlaufend ist, wobei die Ausström-Leitschaufel mit dem in dem Hohlraum strömenden Fluidkörper zusammenwirken kann und einen Teil des Fluids durch den Ausströmschlitz zwingen kann.

**3.** Anti-Vereisungssystem nach Anspruch 2, ferner aufweisend eine Verkleidung (69), die relativ zu der Strömungsrichtung des Fluidkörpers in dem Hohlraum strömungsaufwärts von der Ausström-Leitschaufel angeordnet ist und das Auftreten einer Strömungsablösung verhindern kann.

**4.** Anti-Vereisungssystem nach Anspruch 2 oder 3, ferner aufweisend eine Verkleidung (70), die relativ zu der Strömungsrichtung des Fluidkörpers in dem Hohlraum strömungsabwärts von der Ausström-Leitschaufel angeordnet ist und das Auftreten einer Strömungsablösung verhindern kann.

**5.** Anti-Vereisungssystem nach Anspruch 2, 3 oder 4, bei dem die Ausström-Leitschaufel eine maximale Dicke t gemessen in der Umfangsrichtung und eine abgerundete Vorderkante mit einem Durchmesser d der Vorderkante besitzt und bei dem das Verhältnis d/t zwischen 0,4 und 0,6 liegt.

**6.** Anti-Vereisungssystem nach einem der Ansprüche 2 bis 5, bei dem die Ausström-Leitschaufel eine maximale Dicke t gemessen in der Umfangsrichtung und eine Länge 1 gemessen in der Radialrichtung besitzt und bei dem das Verhältnis t/l zwischen 0,3 und 0,5 liegt.

**7.** Anti-Vereisungssystem nach einem der Ansprüche 2 bis 6, bei dem die Ausström-Leitschaufel und der Ausströmschlitz in einer Richtung rechtwinklig zur Strömungsrichtung des Fluidkörpers in dem Hohlraum verlaufen.

**8.** Anti-Vereisungssystem nach einem der Ansprüche 2 bis 7, bei dem die Ausström-Leitschaufel und der Ausströmschlitz das Fluid in eine radial nach außen gerichtete Richtung abgeben können.

**9.** Anti-Vereisungssystem nach einem der vorhergehenden Ansprüche, bei dem die Ausströmeinrichtung den Teil des Fluids so dreht, daß das Fluid von dem Hohlraum in eine Richtung abgeben wird, die mit der Oberfläche der Gondel einen Winkel $\alpha$ bildet, wobei der Winkel $\alpha$ größer als oder gleich 60° ist.

**10.** Anti-Vereisungssystem nach einem der vorhergehenden Ansprüche, bei dem das Fluid, das abgegeben wird, einen Blasparameter $\beta$ besitzt, der als das Verhältnis der Größe der Geschwindigkeit des abgegebenen Fluids zu der Größe der Geschwindigkeit des über die Gondel strömenden Außenmediums definiert ist, und bei dem der Blasparameter $\beta$ größer als oder gleich 0,4 ist.

**11.** Verfahren zum Verhindern von Eisbildung an einer Gondel (18) einer Flugzeugkraftmaschine (12), wobei die Kraftmaschine eine Quelle (25) für Heizfluid und ein Anti-Vereisungssystem (54) aufweist, das eine Einrichtung (56) zum Strömenlassen von Heizfluid von der Quelle zu einem Hohlraum (52) in der Gondel, eine Einrichtung (58) zum Einströmenlassen von Heizfluid in den Hohlraum und eine Einrichtung (62) zum Ausströmenlassen von Fluid aus dem Hohlraum aufweist, wobei das Verfahren die folgenden Schritte aufweist:

Strömenlassen von Heizfluid von der Quelle zu dem Hohlraum; Einströmenlassen von Heizfluid in den Hohlraum so, daß der Fluidkörper in dem Hohlraum eine umfangsmäßig gerichtete Geschwindigkeitskomponente besitzt; und Abgeben des Fluids aus dem Hohlraum in ein Medium außerhalb der Gondel, wobei das Fluid mit einer Strömungsgeschwindigkeit abgegeben wird, die zum Eindringen in das Außenmedium ausreichend ist,

**dadurch gekennzeichnet,**
daß der Schritt des Abgebens des Fluids das Drehen eines Teils des Fluids in dem Hohlraum in eine zu der Strömungsrichtung des Außenmediums im wesentlichen rechtwinklige Richtung durch eine aerodynamische Ausström-Leitschaufel (66) und einen Ausströmschlitz (68) beinhaltet, wobei die Ausström-Leitschaufel mit dem Fluidkörper in dem Hohlraum zusammenwirken kann, um einen Teil des Fluids zu drehen und den Teil des Fluids durch den Ausströmschlitz zu zwingen.

**12.** Verfahren nach Anspruch 11, bei dem der Schritt des Abgebens des Fluids das Abgeben des Fluids aus dem Hohlraum in eine Richtung beinhaltet, die mit der Oberfläche der Gondel einen Winkel $\alpha$ bildet, wobei der Winkel $\alpha$ größer als oder gleich 60° ist.

**13.** Verfahren nach Anspruch 11 oder 12, bei dem der Schritt des Abgebens des Fluids das Abgeben des Fluids mit einem Blasparameter $\beta$ größer als 0,4 beinhaltet, wobei der Blasparameter $\beta$ als das Verhältnis der Größe der Geschwindigkeit des abgegebenen Fluids zu der Größe der Geschwindigkeit des über die Gondel strömenden Außenmediums ist.

## Revendications

**1.** Système de dégivrage (54) dans une centrale d'énergie (12) ayant un axe longitudinal (14), une source (25) de fluide de chauffage, et une nacelle (18) définissant une entrée du fluide (32) et une limite extérieure (44) dans la direction radiale pour la centrale d'énergie, la nacelle comprenant une cavité annulaire (52) placée autour de l'entrée, le système de dégivrage comprenant des moyens (56) pour faire circuler un fluide de chauffage de la source vers la cavité ; des moyens (58) pour injecter un fluide de chauffage dans la cavité, les moyens d'injection étant adaptés pour former une masse de fluide circulant dans la cavité, avec une composante de vitesse orientée le long de la circonférence ; et des moyens (62) d'échappement du fluide de la cavité vers un milieu extérieur à la nacelle, caractérisé en ce que :

les moyens d'échappement comprennent des vannes (66) placées à l'intérieur de la cavité qui sont aptes à faire tourner une partie du fluide circulant à l'intérieur de la cavité vers une direction sensiblement perpendiculaire à la direction d'écoulement du milieu extérieur à la nacelle et à éjecter le fluide de la cavité dans le milieu extérieur avec une vitesse d'écoulement suffisante pour qu'il pénètre dans le milieu extérieur.

**2.** Système de dégivrage selon la revendication 1, dans lequel la cavité est définie par une coque d'entrée (42) et dans lequel les moyens d'échappement comprennent une fente d'échappement (68) placée sur la partie radialement extérieure de la coque d'entrée et une vanne d'échappement à profil aérodynamique (66), la vanne d'échappement étant placée sur la coque d'entrée, en s'étendant dans la direction radiale vers l'intérieur de la cavité et en étant adjacente et en s'étendant parallèlement à la fente d'échappement, la vanne d'échappement étant apte à venir en prise avec la masse de fluide s'écoulant dans la cavité, et à solliciter une partie du fluide en le faisant passer à travers la fente d'échappement.

**3.** Système de dégivrage selon la revendication 2, comprenant en outre un évasement (69) placé en amont par rapport à la direction d'écoulement de la masse de fluide à l'intérieur de la cavité, par rapport à la vanne d'échappement, et apte à empêcher qu'une séparation de l'écoulement se produise.

**4.** Système de dégivrage selon la revendication 2 ou la revendication 3, comprenant encore un évasement (70) disposé en aval de la vanne d'échappement dans la direction d'écoulement de la masse de fluide à l'intérieur de la cavité et apte à empêcher qu'une séparation de l'écoulement se produise.

**5.** Système de dégivrage selon l'une des revendications 2, 3 ou 4, dans lequel la vanne d'échappement a une épaisseur maximale t mesurée dans la direction de la circonférence et un bord avant arrondi ayant un diamètre du bord avant d, et dans lequel le rapport d/t est compris entre 0,4 et 0,6.

**6.** Système de dégivrage selon l'une quelconque des revendications 2 à 5, dans lequel la vanne d'échappement a une épaisseur maximale t mesurée dans la direction de la circonférence, et une longueur 1 mesurée dans la direction radiale, et dans lequel le rapport t/l est compris entre 0,3 et 0,5.

**7.** Système de dégivrage selon l'une quelconque des revendications 2 à 6, dans lequel la vanne d'échappement et la fente d'échappement s'étendent dans une direction perpendiculaire à la direction de l'écoulement de la masse de fluide à l'intérieur de la cavité.

**8.** Système de dégivrage selon l'une quelconque des revendications 2 à 7, dans lequel la vanne d'échappement et la fente d'échappement sont adaptées pour éjecter le fluide dans une direction radiale vers l'extérieur.

**9.** Système de dégivrage selon l'une quelconque des revendications précédentes, dans lequel les moyens d'échappement font tourner la partie du fluide de manière que le fluide soit éjecté de la cavité dans une direction faisant un angle $\alpha$ avec la surface de la nacelle, l'angle $\alpha$ étant supérieur ou égal à 60°.

**10.** Système de dégivrage selon l'une quelconque des revendications précédentes, dans lequel le fluide à éjecter comporte un paramètre d'éjection $\beta$ défini par le rapport entre l'amplitude de la vitesse du fluide éjecté et l'amplitude de la vitesse du milieu extérieur s'écoulant sur la nacelle, et dans lequel le paramètre d'éjection $\beta$ est supérieur ou égal à 0,4.

**11.** Méthode pour empêcher l'accumulation de glace sur une nacelle (18) d'une centrale d'énergie d'avion (12), la centrale d'énergie comprenant une source (25) de fluide de chauffage et un système de dégivrage (54), le système de dégivrage comprenant des moyens (56) pour faire circuler un fluide de chauffage de la source vers une cavité (52) dans la nacelle ; des moyens (58) pour injecter un fluide de chauffage dans la cavité, et des moyens (62) d'échappement du fluide de la cavité, le procédé comprenant les étapes suivantes : faire écouler le fluide de chauffage de la source vers la cavité ; injecter le fluide de chauffage dans la cavité de manière que la masse du fluide à l'intérieur de la cavité ait une composante de vitesse orientée le long de la circonférence , et éjecter le fluide de la cavité vers un milieu extérieur à la nacelle, le fluide étant éjecté avec une vitesse d'écoulement suffisante pour pénétrer dans le milieu extérieur, caractérisé en ce que :

L'étape d'éjection du fluide comprend la déviation d'une partie du fluide contenu dans la cavité vers une direction sensiblement perpendiculaire à la direction d'écoulement du milieu extérieur au moyen d'une vanne d'échappement aérodynamique (66) et d'une fente d'échappement (68), la vanne d'échappement étant apte à venir en prise avec la masse de fluide à l'intérieur de la cavité pour faire tourner une partie du fluide et solliciter la partie du fluide en la faisant passer à travers la fente d'échappement.

**12.** Procédé selon la revendication 11, dans lequel l'étape d'éjection du fluide comprend l'éjection du fluide de la cavité dans une direction faisant un angle $\alpha$ avec la surface de la nacelle, l'angle a étant supérieur ou égal à 60°.

**13.** Procédé selon la revendication 11 ou la revendication 12, dans lequel l'étape d'éjection du fluide comprend l'éjection du fluide avec un paramètre d'éjection $\beta$ supérieur à 0,4, le paramètre d'éjection $\beta$ étant défini par le rapport entre l'amplitude de la vitesse du fluide éjecté et l'amplitude de la vitesse du milieu extérieur s'écoulant sur la nacelle.

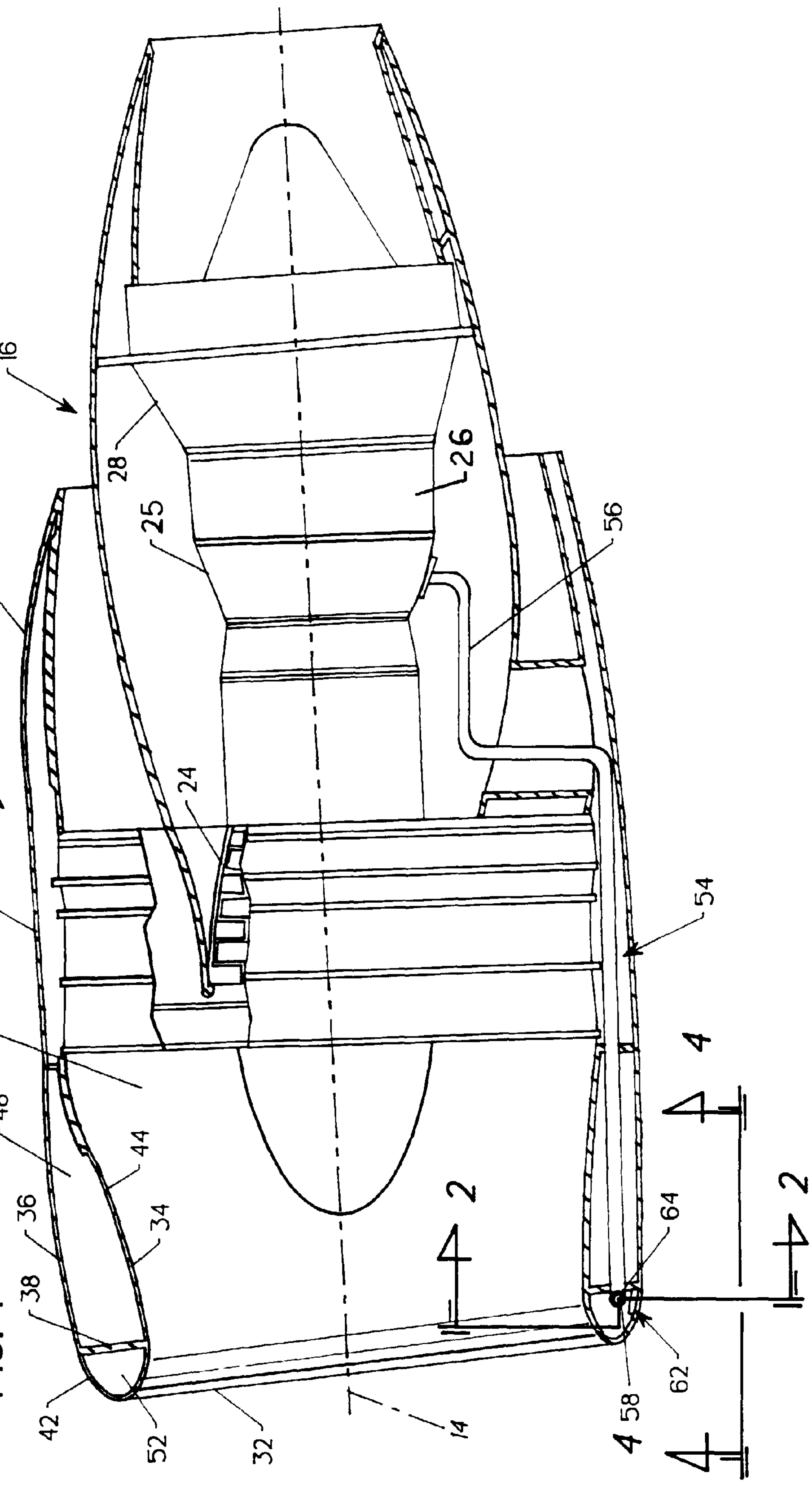
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FIG. 1

FIG. 2

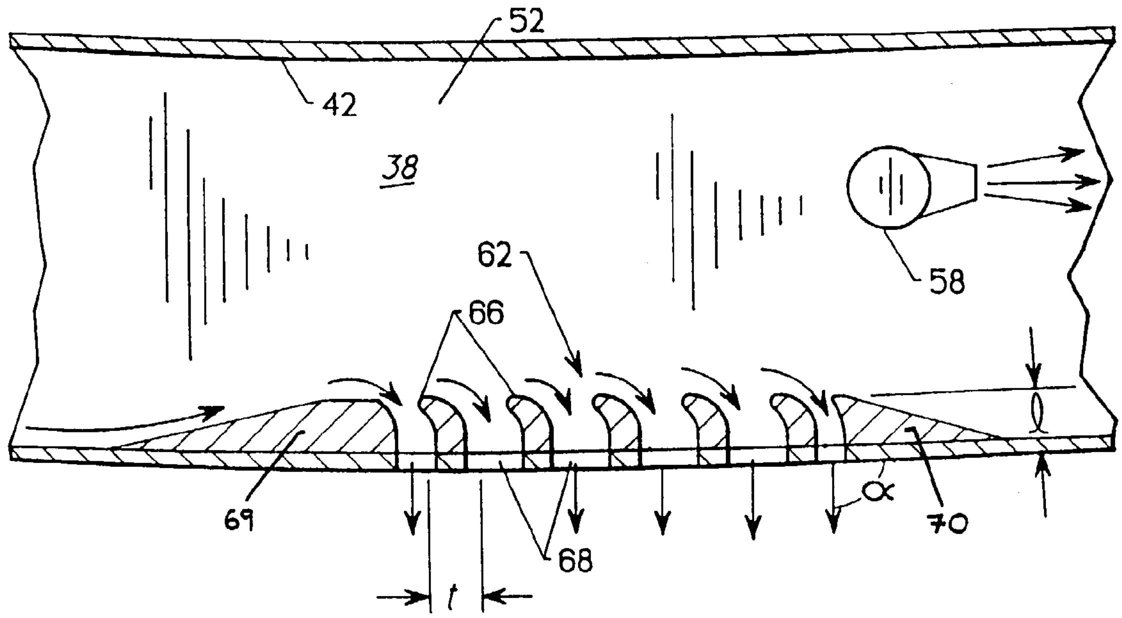


FIG. 4

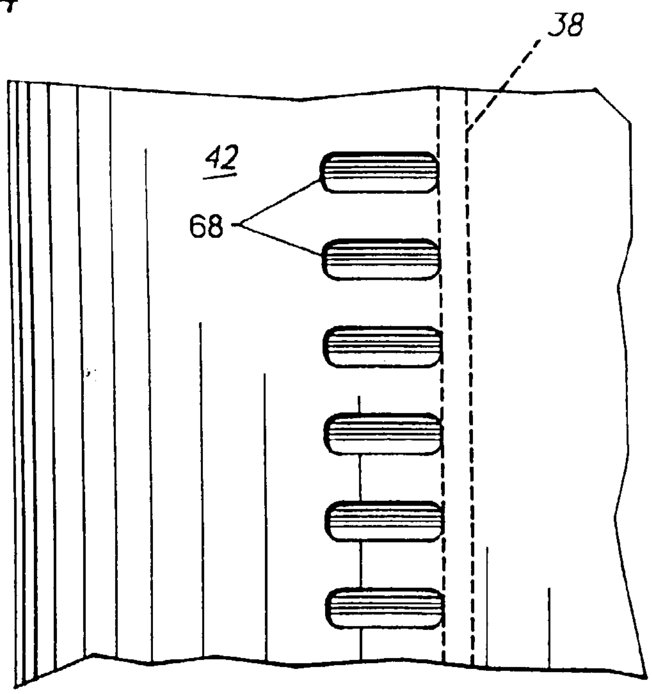

FIG. 3

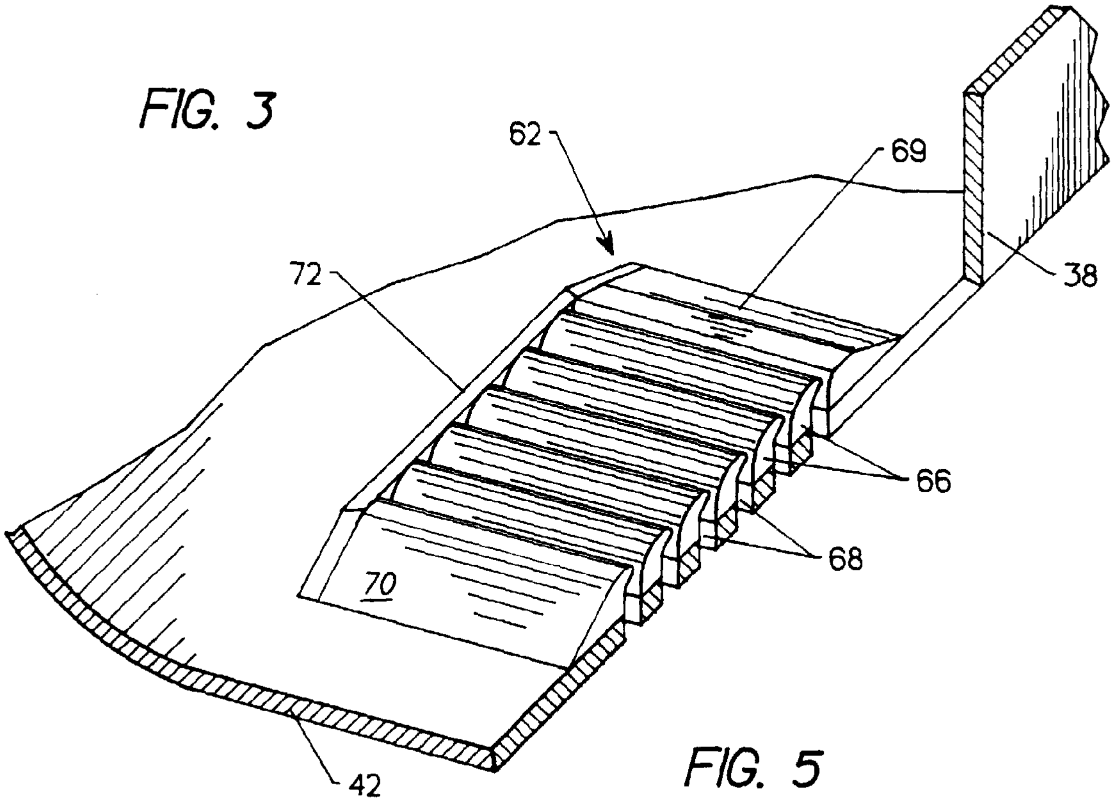


FIG. 5

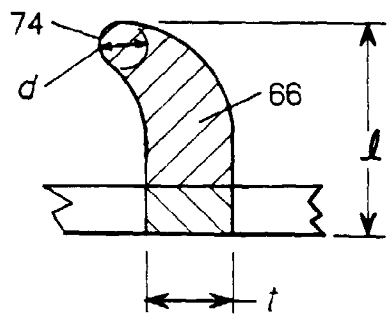


FIG. 6